PATENT ABSTRACTS OF JAPAN

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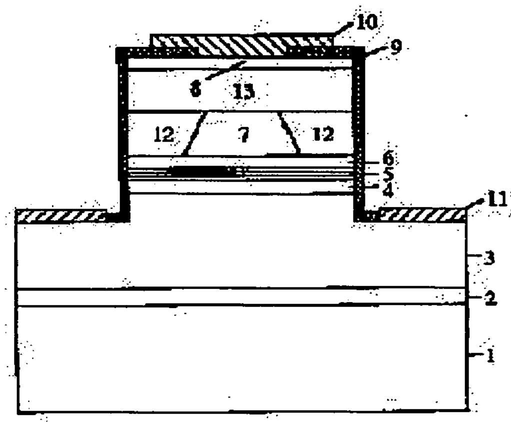
(54) SEMICONDUCTOR LASER ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To reduce the element resistance and the operation voltage of a semiconductor laser in the blue violet wavelength region.
SOLUTION: A semiconductor laser element is constituted of optical waveguide layers 3, 7, 13, light separation and confinement layers 4, 6, an active layer 5 and a contact layer 8. The layers 7, 13, 13 which are P-type crystal layers are made a superlattice heterostructure wherein all of the In composition are modulated, and P-type impurities are subjected to modulation doping by synchronizing the modulated structure of the In composition. Since the positive hole carrier concentration of a P-type optical waveguide layer can be activated nearly one figure higher than the conventional case, resistivity of the P-type optical waveguide layer can be reduced, and contact resistance between a P-type contact layer and a P-side electrode can be also improved. Therefore, the element resistance is reduced to be 1/5-1/10 of the conventional case, and the element operation voltage when the injection current is 20mA can be reduced to be 3.1-3.3V as compared with 3.6V in the conventional case.



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CLAIMS

[Claim(s)]
[Claim 1] The above-mentioned photoconductive wave field be the semiconductor-laser component characterize by to have the superstructure field formed by carry out the laminating of two kinds of semi-conductor layers from which In presentation differ by turns , and to be introduce p mold impurity only into the semi-conductor layer with large In presentation in the above-mentioned superlattice field including the photoconductive wave field which be join by the active region which have a barrier layer , and this barrier layer field , and consist of a semi-conductor with larger forbidden-band width of face than this barrier layer .
[Claim 2] The photoconductive wave field which is joined by the active region which has a barrier layer, and this barrier layer field, and consists of a semi-conductor with larger forbidden-band width of face than this barrier layer, The contact field in which it is joined by this photoconductive wave field, and the current supply source means to this active region is formed is included. The above-mentioned photoconductive wave field and the above-mentioned contact field are a semiconductor laser component characterized by having the superstructure field formed by carrying out the laminating of two kinds of semi-conductor layers from which In presentation differs by turns, and introducing p mold impurity only into the semi-conductor layer with large In presentation in the above-mentioned superlattice field.
[Claim 3] Two kinds of semi-conductor layers which constitute the above-mentioned superstructure field are semiconductor laser components according to claim 1 or 2 characterized by the configuration element except In being the same.
[Claim 4] The semi-conductor layer into which p mold impurity is not introduced among two kinds of semi-conductor layers which constitute the above-mentioned superstructure field in the above-mentioned photoconductive wave field is a semiconductor laser component according to claim 1 to 3 characterized by not including In as a configuration element.
[Claim 5] The above-mentioned barrier layer is a semiconductor laser component according to claim 1 to 4 characterized by consisting of a group III-V semiconducter who contains nitrogen as a configuration element.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is [0002] about the semiconductor laser component suitable for an optical information terminal or the optical application measurement light source. .
[Description of the Prior Art] The component structure which constitutes blue light emitting diode about the light emitting device of a blue field is described in an applied physics letter magazine and 1994 until now in 64 volumes and 1687 - 1689 pages (Appl.Phys.Lett., 64, 1687-1689(1994).), and the example of production of the lightguide using a GaInN/GaN/AlGaN ingredient or a luminescence barrier layer is shown.
[0003]
[Problem(s) to be Solved by the Invention] Although the conventional technique which the above-mentioned paper magazine indicates has described the luminescence barrier layer and the whole lightguide configuration in the blue light emitting diode which used the nitride system ingredient, in this kind of component, the level of p mold carrier concentration of a lightguide is still low, and neither component resistance nor operating voltage is improved enough. Moreover, about the technique of raising p mold carrier concentration, a detail is not explained and reference is not made to the contents about the structure of reducing the component resistance and operating voltage in semiconductor laser with stripe geometry further. For example, in the compound semiconductor laser which consists of an III-V group element, p mold lightguide and p mold contact layer are prepared between a barrier layer and p lateral electrode. These layers inject II group element (for example, Mg) into the compound semiconductor layer of an III-V group element as a dopant, and are formed. The dopant of II group element replaces and goes into an III group element to the site to which an III group element exists in the crystal of a compound semiconductor. Since there are few a peripheral electrons compared with an III group element, if II group element with few one peripheral electron goes into this site, it will serve as a cation, namely, will offer an electron hole. This electron hole serves as a carrier in a p type semiconductor, and that amount determines the component resistance and operating voltage in a semiconductor laser component. By the way, begin above-mentioned blue light emitting diode, and it sets to light emitting devices, such as a semiconductor laser component. The dopant ion concentration [in obtaining the component resistance and operating voltage which are sufficient for practical use] in above-mentioned p mold lightguide Although it is requested that (namely, II group element concentration which went into the site of an III group element and was ionized) should be carried out more than 5x1018cm~3-1x1019cm~3 or this about 5x1017cm~3-1x1018cm~3 or more than this, and p mold contact layer This concentration was actually saturated with 5x1016cm~3-1x1017cm~3 to the injection rate of a dopant in the GaN layer, therefore carrier concentration of p mold lightguide or p mold contact layer was not able to be raised enough.
[0004] Especially, with an III-V group nitride system compound semiconductor ingredient, the main purposes of this invention realize resistivity reduction of difficult p mold lightguide, and attain the reduction in resistance of a laser component and the reduction in operating voltage which consist of the compound semiconductor concerned. Moreover, the refractive index of p mold lightguide is raised desirably, the large guided wave structure of the optical confinement effectiveness is formed near the barrier layer of a semiconductor laser component, and luminous efficiency is raised. attaining these purposes — especially, laser actuation (laser beam oscillation) of the purple-blue color wavelength field in the device which consists of a nitride system compound semiconductor ingredient — a low threshold — and it can realize with low resistance low operating voltage, and dependability is raised over a long period of time.
[0005]
[Means for Solving the Problem] In order to improve especially the level of the carrier concentration in the p type semiconductor layer whose bulk growth of a nitride system semi-conductor was inadequate in production of the semiconductor laser which consists of a compound semiconductor first in this invention in attaining the above-mentioned purpose The crystal layer (semi-conductor layer) which introduced suitable In element for activation of p mold carrier is prepared as a lightguide which is joined to a barrier layer or is prepared in this through other semi-conductor layers (barrier layer etc.). The superlattice hetero structure which modulated In presentation by atomic layer order in this crystal layer, and was synchronized with this, and carried out the modulation dope of the p mold impurity is formed. Namely, the photoconductive wave field which is joined by the active region which has a barrier layer, and the barrier layer field concerned in this invention, and consists of a semi-conductor with larger forbidden-band width of face than this barrier layer is included. It has the superstructure field formed by a photoconductive wave field carrying out the laminating of two kinds of semi-conductor layers from which In presentation differs by turns, and the semiconductor laser component equipped with p mold impurity being introduced only into the semi-conductor layer with large In presentation in the superlattice field as fundamental requirements for a configuration is produced. Moreover, the superstructure field where

the laminating of two kinds of semi-conductor layers from which In presentation differs was carried out to this contact field by turns, and it was formed in it including the contact field where it is further joined to this fundamental requirement for a configuration by the photoconductive wave field, and the current supply source means to an active region is formed in it, and p mold impurity was introduced only into the semi-conductor layer with large In presentation of them may be formed. This semiconductor laser component is formed as what has the so-called duplex junction structure which usually sandwiched the small luminescence barrier layer of the forbidden-band width of face prepared in the semi-conductor substrate upper part of a single crystal by the lightguide with big forbidden-band width of face. p mold carrier concentration of the high layer of In presentation ratio in an above-mentioned superlattice field is the range of three or less 1019-/cm, and it is desirable to set up so that it may be activated on level with the electron hole carrier concentration higher than the case where p mold impurity is doped uniformly in the lightguide concerned. In any case, the direction where it is good also as the same (for example, GaPN and GaInPN), and p mold impurity is not introduced among these semi-conductor layers in the configuration element excluding [two kinds of semi-conductor layers which constitute these superstructure fields] In may be formed so that In may not be included as a configuration element. Furthermore, a barrier layer may be constituted from a group III-V semiconducter who contains nitrogen as a configuration element, and may form the so-called multiplex quantum well structure where such a two or more layers barrier layer was prepared in the above-mentioned active region.

[0006] If the outline of the semiconductor laser component configuration of this invention stated above is put in another way by the example, in the semiconductor laser component which consists of the conventional group III-V semiconducter, the place which transposes an AlGaN lightguide to the superstructure which consists of an AlGaN/AlGaInN layer, respectively will become the superstructure which a GaN lightguide becomes from a GaN/GaInN layer with the 1st description. Moreover, it considers as the superlattice hetero structure which carried out the laminating of a GaInN layer with small In presentation of p mold contact layer in contact with p lateral electrode, and the GaInN layer with big In presentation by turns, and the place which introduces p mold impurity into a GaInN layer with big In presentation serves as the 2nd description. That is, the lightguide by which a laminating is carried out to the method of p lateral electrode of a semiconductor laser component in this invention () Or two kinds of semi-conductor layers from which In presentation differs in formation of a cladding layer and a contact layer (one side) Prepare the superstructure field which consists of In not being included, it is made to synchronize with thin film growth of the atomic layer order of the semi-conductor layer (layer into which In was introduced to the layer which does not contain In) which enlarged In presentation of this field, and the technique of carrying out the modulation dope of the p mold impurity is used for this. p mold impurity — for example, Mg or Zn — as the raw material of a simple substance or an organometallic compound — using — molecular beam epitaxy (MBE) — law or organic metal vapor growth (MOVPE) — it introduces by law. When it constitutes a lightguide from a GaN layer or an AlGaN layer, and a compound semiconductor layer that introduced In into this, p mold impurity dope is good to carry out so that average p mold carrier concentration in p mold lightguide whole region may go into the range of 5x1017 to 5x1018-/cm3. Moreover, p mold impurity dope in p mold contact layer which consists of two kinds of GaInN layers from which In presentation differs is good to carry out so that average p mold carrier concentration in the contact layer whole region concerned may go into the range of 5x1018 to 2x1019-/cm3. Desirably, all of the lightguide and contact layer of the method of p lateral electrode are formed by the superstructure by this technique. In this invention, without changing the substantial forbidden-band width of face of a lightguide a lot, a high-concentration electron hole carrier is obtained and increase of the refractive index accompanying installation of In presentation can be utilized for the optical confinement in a luminescence barrier layer. By these, it operates by the low threshold current and the component which reduced component resistance and operating voltage is realized.

[0007] Furthermore, if the desirable additional requirements for a configuration are specified for the laser component of this invention, it will be good to constitute so that a compressive strain or an optically biaxial lattice strain may join p mold lightguide by installation of In presentation in the 1st, and to hold down each thickness of the In installation layer concerned to under critical thickness in p mold lightguide whole region. The semi-conductor substrate of the single crystal used as the base for constituting a laser component in the 2nd is desirable to formation of the laser component which becomes being the silicon carbide (alpha-SiC) which has the sapphire (alpha-aluminum 2O3) substrate or (0001) C side which has C (0001) side with the Wurtzite structure of hexagonal system from a nitride system compound semiconductor especially. In this case, in case optical waveguide structure is established on a hexagonal system Wurtzite structure substrate, it is good to be parallel to the Ath (11-20) page of a substrate, or to set up the direction which forms waveguide in the direction which becomes perpendicular. Moreover, optical waveguide may be constituted in the embedding mold (BH) stripe geometry which establishes a real refractive-index difference to the longitudinal direction of a luminescence barrier layer as stripe geometry with a rectangle-like cross-section configuration and by which the guided wave of the basic transverse mode is carried out to stability. The crystal layer which constitutes rectangle-like optical waveguide structure is good to form BH stripe geometry with an insulator layer mask and a selective growth technique. Even if it constitutes it from a single quantum well layer, it is good also as multiplex quantum well structure which consists of two or more quantum wells, and a luminescence barrier layer [in / as the 3rd / the active region of semiconductor laser] is good also as the single which constituted the luminescence barrier layer by the deformation amount child well layer which introduced the lattice strain, or multiplex deformation amount child well structure so that it may extend the degree of freedom of the material selection of a luminescence barrier layer and the barrier layer which confines an electron or an electron hole (carrier) in this.

[0008] The basis of an operation characteristic of an above-mentioned component configuration is explained below.

[0009] In order to activate a high level conventionally and to set up the electron hole carrier concentration of p mold lightguide, the technique of synchronizing with the modulated structure of the above-mentioned In presentation, and

introducing p mold impurity is applied. In element acts in the direction which makes small forbidden-band width of face of the semi-conductor to every semiconductor material. Since forbidden-band width of face is made small and spacing of a valence band and impurity level is especially narrowed relatively also to a nitride semiconductor material, carrier activation of p mold impurity will be promoted. For example, since the rate of activation can be improved also in the same amount of p mold impurities by considering as a GaInN crystal layer to a GaN crystal layer, high electron hole carrier concentration can be set up. Therefore, according to this invention, in the lightguide of a semiconductor laser component, the electron hole carrier concentration to 1019-/cm3 can be set as arbitration.

[0010] Explanation of model invention is further continued using a reductio ad absurdum. For example, if In presentation is introduced into the lightguide, this forbidden-band width of face will become small, and when the forbidden-band width of face of a luminescence barrier layer is approached, guided wave light will receive absorption. By this invention, absorption by the lightguide of the light which emitted light from the barrier layer and which should be carried out a guided wave is prevented to this problem as superlattice hetero structure where In presentation was modulated by atomic layer order. That is, in p mold lightguide, it is made to synchronize with modulating In presentation by atomic layer order, and p mold impurity is introduced, and in order not to decrease forbidden-band width of face greatly, it is considering as superlattice hetero structure. Incidentally with the semi-conductor layer of atomic layer order, it is specifically specified as a part for number atomic layer thickness, and the thing which has the thickness around 10A on the basis of the magnitude of 5.166A of one atom which constitutes this (diameter) (since the laminating of the atom is carried out to the shape of a hound's-tooth check). Moreover, although p mold contact layer in contact with p lateral electrode is made into the superstructure which consists of two sorts of p mold GaInN layers from which In presentation ratio differs, by modulating In presentation still more greatly, introducing a compressive strain into this (enlarging the difference of In presentation ratio of a high In concentration layer and a low In concentration layer) superstructure, and bending the band structure of a valence band, electron hole carrier concentration is activated more and high conductivity is attained. It has been small improved by the contact resistance of p lateral electrode by this invention, and p mold contact layer even in one to 5x10~6-ohmcm2.

[0011] Moreover, since the electron hole carrier concentration of p mold lightguide becomes high by this invention, the pseudo-Fermi level is set up more highly and the energy barrier of p mold lightguide to a luminescence barrier layer can be set up greatly. For this reason, since the overflow carrier (electron which goes into p mold lightguide from a barrier layer, without contributing to luminescence) from a barrier layer was controlled, it was possible to have improved eye carrier ****** in a barrier layer. To the component property, the effectiveness of low threshold actuation or the operational stability under an elevated temperature was also seen.

[0012] Establishing the superlattice hetero structure which modulated In presentation near the barrier layer leads to the ability of the optical confinement factor in a barrier layer to be designed greatly compared with the lightguide which does not introduce In presentation. This is because the refractive index of the crystal layer which introduced In presentation can be enlarged, and the magnitude of In presentation and the thing which introduced and for which the optical confinement of a barrier layer is designed and adjusted by the thickness of a thin film layer or the total thickness of a superstructure are repeatedly possible for it. By carrying out the optimum design of this optical confinement factor, low threshold efficient actuation and elevated-temperature actuation can be obtained, and the aspect ratio of a far field pattern can be adjusted.

[0013] It was possible to have reduced the operating voltage at the time of the reduction in resistance and laser oscillation of a component by the above. Moreover, the low threshold of a component and efficient actuation were attained by applying the refractive-index guided wave stripe geometry which can attain stabilization of the basic transverse mode.

[0014]

[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention described in an example 1 thru/or 5, and these related drawings explains this invention to a detail.

[0015] One example of <example 1> this invention is explained to be drawing 1 (a) by (b). On the sapphire (alpha-aluminum 2O3) substrate 1 which has C (0001) side of drawing 1 (a) first After heat-treating a substrate in 1200 degrees C from the temperature of 1000 degrees C, supplying ammonia NH3 by metal-organic chemical vapor deposition, In the temperature of 450-550 degrees C, grow up and the GaN buffer layer 2 is set in temperature of 1000-1100 degrees C. The n mold GaN lightguide 3, the n mold AlGaN lightguide 4, An undoping GaN quantum barrier layer And the compressive strain multiplex quantum well barrier layer 5 which consists of an undoping GaInN quantum well layer, the p mold AlGaN/AlGaInN superlattice hetero structure lightguide 6, the p mold GaN/GaInN superlattice hetero structure lightguide 7, and the p mold GaInN/GaInN superlattice hetero structure contact layer 8 It prepares. Under the present circumstances, p mold lightguide 6, p mold lightguide 7, and p mold contact layer 8 were made into the superlattice hetero structure where In presentation was modulated altogether, as typically shown in drawing 1 (b), they formed the lightguide and the contact layer by the repeat of the superlattice thin film layer of atomic layer order, and Mg of p mold impurity is synchronized with the modulated structure of In presentation, and they have introduced it. Therefore, Mg is doped by the AlGaInN layer of a lightguide 6, the GaInN layer of a lightguide 7, and the GaInN layer (direction of In presentation size) of the contact layer 8, and nothing is doped by the AlGaN layer of a lightguide 6, the GaN layer of a lightguide 7, and the GaInN layer (direction of In presentation smallness) of the contact layer 8. In the form of an organometallic compound, p mold impurity Mg was introduced into p mold lightguide 6 and p mold lightguide 7 in the range of 5x1017 to 2x1018-/cm3, and introduced it into p mold contact layer 8, respectively in the range of 5x1018 to 2x1019-/cm3. Next, by photolithography and etching processing, as shown in drawing 1 (a), a part of crystal layer is removed until it results in a layer 3. Then, an insulator layer 9 is formed and the direction of a window region stripe is formed in the direction parallel to the Ath page in this 2Oalpha-aluminum 3 substrate 1 (11-20). Moreover, the pattern of the p lateral electrode 10 and the n lateral electrode 11 is vapor-deposited with lithography. Finally, the component cross section shown in drawing 1 (a) is obtained by carrying out

cleavage of the substrate in the perpendicular direction to an optical waveguide stripe.

[0016] Since the electron hole carrier concentration of the p mold GaN and an AlGaN lightguide was more highly [than before / an about single figure] activable according to this example, the resistivity of p mold lightguide has been reduced. Furthermore, the contact resistance of p mold contact layer and p lateral electrode can also be small improved even in one to 5x10^-6-ohmcm2. Thereby, component resistance of this example could be reduced from 1/5 of the conventional component to 1/10 (it is dependent on In presentation ratio of each class), and has reduced 20mA o'clock [of inrush currents] component operating voltage even to 3.1-3.3V to conventional 3.6V further. Moreover, since electron hole carrier concentration can be made high by this invention, the pseudo-Fermi level of p mold lightguide can be made higher. Thereby, the energy barrier of p mold lightguide to a luminescence barrier layer was able to be enlarged. As for this, it was possible to have controlled the overflow carrier from a barrier layer, and for the carrier in a barrier layer to have closed, and to have made eye ** improve. Furthermore, since In is contained in p mold lightguide, the refractive index becomes high and enlarges the optical confinement factor near the luminescence barrier layer. This component structure had the stripe geometry of a gain guided wave mold, and in a room temperature, laser actuation is possible for it, and it obtained the component which carries out laser oscillation in the range which is 410-430nm of a purple-blue color wavelength region.

[0017] Drawing 2 explains other examples of <example 2> this invention. After forming in the GaN/GaInN superlattice of p mold to the terrorism assembling-die lightguide 7, the insulator layer mask extended in the shape of a stripe in the top-face center section of the lightguide 7 with photolithography is formed, further, although a component is produced like an example 1, a lightguide 7 is removed and a ridge stripe is formed by etching using this insulator layer mask, until the top face of the p mold AlGaN/AlGaInN superlattice heterojunction mold lightguide 6 is exposed. Next, selective growth of the n mold GaN current constriction layer 12 is carried out using an insulator layer mask. After removing an insulator layer mask, the p mold GaN/GaInN superlattice hetero structure embedding layer 13 and the p mold GaInN/GaInN superlattice hetero structure contact layer 8 are formed. Next, by photolithography and etching processing, as shown in drawing 2 , the both sides of ridge stripe geometry are removed until it results in a layer 3. Then, a component is produced completely like an example 1.

[0018] Since it was made to the refractive-index guided wave structure where the current constriction layer 12 was formed according to this example, the component of a low threshold was obtained rather than the example 1. The threshold current has been reduced even from 1/3 to 1/5 compared with the example 1. The range of a purple-blue color wavelength region of oscillation wavelength was 410-430nm.

[0019] Drawing 3 explains other examples of <example 3> this invention. First, it prepares to the GaN lightguide 3 of n mold like an example 1 or 2. Next, the insulator layer mask 14 for selective growth of two articles extended in the shape of a stripe is formed in lightguide 3 top face by photolithography and etching. Then, selective growth of the compressive strain multiplex quantum well barrier layer 5 which becomes a start from the n mold AlGaN lightguide 4, an undoping GaN quantum barrier layer, and an undoping GaInN quantum well layer about re-growth of the n mold GaN lightguide 3, the p mold AlGaN/AlGaInN superlattice hetero structure lightguide 6, the p mold GaN/GaInN superlattice hetero structure lightguide 7, and the p mold GaInN/GaInN superlattice hetero structure contact layer 8 is carried out by metal-organic chemical vapor deposition. That is, at the process from re-growth of a lightguide 3, since crystal growth has arisen alternatively in the field divided with the stripe-like insulator layer mask whose number is two, the layered product of a crystal which has a rectangle cross section as shown in drawing 3 is formed. Then, an insulator layer 9 is formed and vacuum evaporationo formation of the pattern of the p lateral electrode 10 and the n lateral electrode 11 is carried out with lithography. Furthermore, the component cross section shown in drawing 3 is obtained by carrying out cleavage of the substrate in the direction perpendicular to waveguide.

[0020] According to this example, BH stripe geometry which guides the basic transverse mode to stability according to a real refractive-index difference was producible. With this component, rather than the component of an example 1, since the large refractive-index difference of a barrier layer longitudinal direction can be taken, guided wave light can be spread to stability. Furthermore, since the current constriction effectiveness was also large, low threshold actuation was possible. The threshold current has been reduced even from 1/2 to 1/3 to the pan compared with the example 2. The range of a purple-blue color wavelength region of oscillation wavelength was 410-430nm.

[0021] Drawing 4 explains other examples of <example 4> this invention. Although a component is produced like an example 3, selective growth of the same crystal layer as an example 3 is carried out using the insulator layer mask 14 containing a dummy pattern as shown in the outside of BH stripe geometry equivalent to an example 3 at drawing 4 . A dummy pattern is a selective growth field (field divided with the insulator layer mask) which prepares one articles of insulating stripe-like masks at a time in abbreviation parallel, and is formed in these on the outside of the insulating mask of the shape of a stripe of two articles established by component formation of drawing 3 and which was newly formed when putting in another way. To the stripe on a dummy pattern, the insulator layer mask 9 is carried out like drawing 4 , is covered, and it is made not to pour in a current. Then, the component cross section shown in drawing 4 is obtained by vapor-depositing an electrode and carrying out cleavage of the substrate.

[0022] According to this example, the crystallinity of the waveguide crystal layer in BH stripe geometry of a center section is improvable with the dummy pattern. Consequently, compared with an example 3, low threshold actuation is possible, and the threshold current has been reduced from the example 3 from 2/3 to 1/2 to the pan. Also about quantum efficiency, it has increased 50% from 30% from the example 3. The range of a purple-blue color wavelength region of oscillation wavelength was 410-430nm.

[0023] Other examples of <example 5> this invention are explained. In this example, in the semiconductor laser component which has the component configuration of already explained drawing 1 thru/or either of 4, an n mold GaN buffer layer is

prepared on it at a substrate 1 using the silicon carbide (alpha-SiC) of n mold whose substrate side bearing it is the Wurtzite structure of hexagonal system and is C (0001) side, and a component is produced according to a publication of an example 1 thru/or either of 4.

[0024] According to this example, since a substrate had the conductivity of n mold, the electrode by the side of n was able to be vapor-deposited at the substrate rear face, and was able to conduct the current to the substrate vertical side. Since mounting which turned the joint down at the time of the assembly of a chip type element was attained by this, heat leakage nature has been improved. In this example, the laser component which operates at temperature higher than the above-mentioned example was obtained.

[0025]

[Effect of the Invention] Especially in this invention, in the III-V group nitride semiconductor material, since the electron hole carrier concentration of p mold lightguide can be set now as arbitration to 1019-/cm3 and the carrier was activated highly an about single figure rather than before, the resistivity of p mold lightguide has been reduced. Furthermore, the contact resistance of p mold contact layer and p lateral electrode was reduced, and it has improved small even in one to 5x10~6-ohmcm2. With the component of this invention, while reducing the resistance from 1/5 to 1/10 conventionally, 20mA o'clock [of inrush currents] component operating voltage has been conventionally reduced even to 3.1-3.3V to having been 3.6V. Moreover, with high electron hole carrier concentration, since the pseudo-Fermi level in p mold lightguide was made higher, the energy barrier of p mold lightguide to a barrier layer has been set up more greatly than the conventional technique: a carrier [in / in this / a barrier layer] -- it was effective in shutting up. Furthermore, since In presentation which makes a refractive index high was incorporated by p mold lightguide, the optical confinement factor near the luminescence barrier layer has been designed greatly. According to such effectiveness, with the component of this invention, it is low component resistance, and was able to operate with low operating voltage, and low threshold actuation was able to be aimed at. By this invention, the laser actuation which consists of an AlGaInN ingredient was checked in the room temperature, and the component which carries out laser oscillation in the wavelength field of a purple-blue color in the range with an oscillation wavelength of 410-430nm was obtained.

[0026] Although this invention explained the AlGaInN semiconductor laser component produced on the sapphire of Wurtzite structure with C (0001) side, or a silicon-carbide-monocrystal substrate, it cannot be overemphasized that it is applicable to the semiconductor laser component using AlInGaAs/GaAs, AlGaInP/GaAs, GaInAsP/GaInAs/InP, AlInAs/GaInAs/InP, etc. which are other semiconductor material systems.

[Translation done.]

* NOTICES *

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing for explaining the example 1 of this invention, and (a) is component structure drawing of longitudinal section, and (b) is a superstructure p mold impurity modulation dope crystal layer.
[Drawing 2] It is component structure drawing of longitudinal section showing the example 2 of this invention.
[Drawing 3] It is component structure drawing of longitudinal section showing the example 3 of this invention.
[Drawing 4] It is component structure drawing of longitudinal section showing the example 4 of this invention.
[Description of Notations]
1 — (0001) C side sapphire single crystal substrate, 2 — GaN buffer layer, 3 — An n mold GaN lightguide, 4 — An n mold AlGaN light separation confining layer, 5 — GaInN/GaN compressive strain multiplex quantum well structure barrier layer, 6 — A p mold AlGaN light separation confining layer, 7 — Superlattice hetero structure p mold impurity modulation dope GaN lightguide, 8 [— n lateral electrode, 12 / — An n mold GaN current constriction layer, 13 / — A superlattice hetero structure p mold impurity modulation dope GaN embedding layer, 14 / — Insulator layer mask for selective growth.] — A superlattice hetero structure p mold impurity modulation dope GaInN contact layer, 9 — An insulator layer, 10 — p lateral electrode, 11

[Translation done.]

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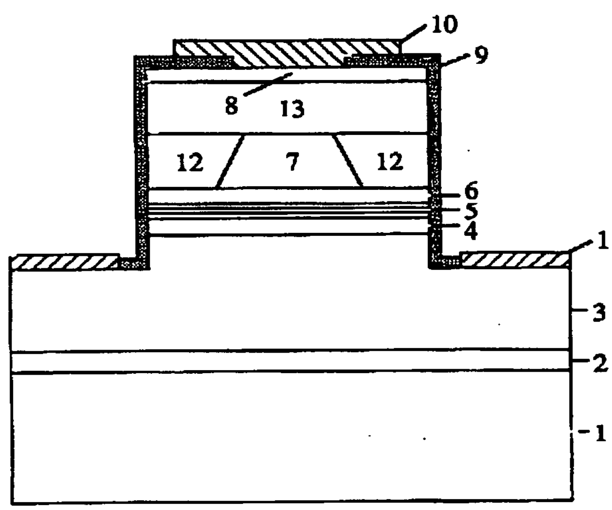
(54)【発明の名称】　半導体レーザ素子

(57)【要約】
【課題】青紫色波長域の半導体レーザの素子抵抗や動作電圧を低減する。
【解決手段】光導波層３，７，１３、光分離閉じ込め層４，６、活性層５、コンタクト層８からなる半導体レーザ素子において、ｐ型結晶層である層７，１３，１３は、すべてIn組成を変調した超格子ヘテロ構造とし、In組成の変調構造に同期させてｐ型不純物を変調ドープする。
【効果】ｐ型光導波層の正孔キャリア濃度を従来よりも一桁近く高く活性化できたので、ｐ型光導波層の抵抗率を低減でき、ｐ型コンタクト層とｐ側電極の接触抵抗も改善できた。これにより、素子抵抗を従来の1/5から1/10に低減するとともに、注入電流２０ｍＡ時の素子動作電圧を従来の３．６Ｖに対して３．１～３．３Ｖにまで低減できた。

図２



【特許請求の範囲】
【請求項１】活性層を有する活性領域と、該活性層領域に接合され且つ該活性層より禁制帯幅の大きい半導体からなる光導波領域とを含み、上記光導波領域はIn組成の異なる２種類の半導体層を交互に積層して形成された超格子構造領域を有し、上記超格子領域においてIn組成の大きい半導体層のみにｐ型不純物が導入されていることを特徴とする半導体レーザ素子。
【請求項２】活性層を有する活性領域と、該活性層領域に接合され且つ該活性層より禁制帯幅の大きい半導体からなる光導波領域と、該光導波領域に接合され且つ該活性領域への電流供給手段が設けられるコンタクト領域を含み、上記光導波領域及び上記コンタクト領域はIn組成の異なる２種類の半導体層を交互に積層して形成された超格子構造領域を有し、上記超格子領域においてIn組成の大きい半導体層のみにｐ型不純物が導入されていることを特徴とする半導体レーザ素子。
【請求項３】上記超格子構造領域を構成する２種類の半導体層は、Inを除く構成元素が同一であることを特徴とする請求項１又は２に記載の半導体レーザ素子。
【請求項４】上記光導波領域における上記超格子構造領域を構成する２種類の半導体層のうち、ｐ型不純物が導入されない半導体層はInを構成元素として含まないことを特徴とする請求項１乃至３のいずれか一に記載の半導体レーザ素子。
【請求項５】上記活性層は、構成元素として窒素を含むIII－Ｖ族化合物半導体からなることを特徴とする請求項１乃至４のいずれか一に記載の半導体レーザ素子。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、光情報端末或は光応用計測光源に適する半導体レーザ素子に関する
【０００２】。
【従来の技術】これまで青色領域の発光素子に関して、青色発光ダイオードを構成する素子構造がアプライド・フィジックス・レター誌，1994年，64巻，1687-1689頁(Appl. Phys. Lett., 64, 1687-1689(1994).)において述べられており、GaInN/GaN/AlGaN材料を用いた光導波層や発光活性層の作製例が示されている。
【０００３】
【発明が解決しようとする課題】上記論文誌が開示する従来技術では、窒化物系材料を用いた青色発光ダイオードにおける発光活性層や光導波層の全体構成について述べているが、この種の素子においては、まだ光導波層のｐ型キャリア濃度のレベルが低く、素子抵抗や動作電圧が十分改善されていない。また、ｐ型キャリア濃度を向上させる手法については詳細を説明しておらず、さらにストライプ構造を有した半導体レーザにおける素子抵抗及び動作電圧を低減する構造に関した内容に対して言及していない。　例えば、III－Ｖ族元素からなる化合物半導体レーザにおいて、活性層とｐ側電極との間にｐ型光導波層とｐ型コンタクト層を設ける。これらの層は、III－Ｖ族元素の化合物半導体層にII族元素（例えば、Ｍｇ）をドーパントとして注入して形成される。II族元素のドーパントは、化合物半導体の結晶においてIII族元素が存在するサイトにIII族元素に替わって入る。最外殻電子が１つ少ないII族元素は、III族元素に比べて最外殻電子が１つ少ないため、このサイトに入ると正イオンとなり、即ち正孔を提供する。この正孔はｐ型半導体においてキャリアとなり、その量は半導体レーザ素子における素子抵抗や動作電圧を決める。ところで、上述の青色発光ダイオードをはじめ、半導体レーザ素子等の発光素子においては、実用に足る素子抵抗と動作電圧を得るにあたり、上述のｐ型光導波層におけるドーパントイオン濃度（即ち、III族元素のサイトに入ってイオン化したII族元素濃度）を$5\times10^{17}cm^{-3}$～$1\times10^{18}cm^{-3}$又はこれ以上、ｐ型コンタクト層については$5\times10^{18}cm^{-3}$～$1\times10^{19}cm^{-3}$又はこれ以上にすることが要請されているが、現実にはGaN層にドーパントの注入量に対し、この濃度は$5\times10^{16}cm^{-3}$～$1\times10^{17}cm^{-3}$で飽和し、従ってｐ型光導波層やｐ型コンタクト層のキャリア濃度を充分高めることはできなかった。
【０００４】本発明の主要な目的は、特にIII-Ｖ族窒化物系化合物半導体材料では困難であったｐ型光導波層の抵抗率低減を実現し、当該化合物半導体からなるレーザ素子の低抵抗化と低動作電圧化を図るものである。また、望ましくはｐ型光導波層の屈折率を高めて、半導体レーザ素子の活性層近傍に光閉じ込め効果の大きい導波構造を形成して発光効率を高める。これらの目的を達成することにより、特に窒化物系化合物半導体材料からなるデバイスにおける青紫色波長領域のレーザ動作（レーザ光発振）を低閾値でかつ低抵抗低動作電圧で実現でき、また長期信頼性を高める。
【０００５】
【課題を解決するための手段】上記目的を達成するにあたり、本発明ではまず化合物半導体からなる半導体レーザの作製において、特に窒化物系半導体のバルク成長では不十分であったｐ型半導体層におけるキャリア濃度のレベルを改善するために、ｐ型キャリアの活性化に好適なIn元素を導入した結晶層（半導体層）を活性層に接合され又はこれに他の半導体層（障壁層等）を介して設けられる光導波層として設け、この結晶層において原子層オーダでIn組成を変調し且つこれに同期させてｐ型不純物を変調ドープした超格子ヘテロ構造を形成する。即ち、本発明では、活性層を有する活性領域と、当該活性層領域に接合され且つこの活性層より禁制帯幅の大きい半導体からなる光導波領域とを含み、光導波領域はIn組成の異なる２種類の半導体層を交互に積層して形成された超格子構造領域を有し、その超格子領域においてIn組成の大きい半導体層のみにｐ型不純物が導入されている

ことを基本的な構成要件として備えた半導体レーザ素子を作製する。また、この基本的な構成要件に、さらに光導波領域に接合され且つ活性領域への電流供給手段が設けられるコンタクト領域を含め、このコンタクト領域にIn組成の異なる２種類の半導体層を交互に積層して形成され且つそのうちのIn組成の大きい半導体層のみにｐ型不純物が導入された超格子構造領域を形成しても良い。この半導体レーザ素子は、通常、単結晶の半導体基板上部に設けられた禁制帯幅の小さな発光活性層を禁制帯幅の大きな光導波層で挟んだ所謂二重接合構造を有するものとして形成される。上述の超格子領域におけるIn組成比の高い層のｐ型キャリア濃度は、$10^{19}/cm^3$以下の範囲で且つｐ型不純物を一様にドープした場合よりも当該光導波層における正孔キャリア濃度が高いレベルに活性化するように設定することが望ましい。いずれの場合も、これらの超格子構造領域を構成する２種類の半導体層は、Inを除く構成元素を同一（例えばGaPNとGaInPN）としてもよく、またこれらの半導体層のうち、ｐ型不純物が導入されない方はInを構成元素として含まないように形成しても良い。さらに活性層は、構成元素として窒素を含むIII－V族化合物半導体で構成し、このような活性層を上述の活性領域に複数層設けた所謂多重量子井戸構造を形成しても良い。

【０００６】以上に述べた本発明の半導体レーザ素子構成の概要を具体例で言い替えれば、従来のIII－V族化合物半導体からなる半導体レーザ素子において、GaN光導波層はGaN/GaInN層からなる超格子構造に、AlGaN光導波層はAlGaN/AlGaInN層からなる超格子構造にそれぞれ置き換えるところが第１の特徴となる。また、ｐ側電極と接触するｐ型コンタクト層を、In組成の小さなGaInN層とIn組成の大きなGaInN層を交互に積層した超格子ヘテロ構造とし、In組成の大きなGaInN層にはｐ型不純物を導入するところが第２の特徴となる。つまり、本発明では半導体レーザ素子のｐ側電極方に積層される光導波層（又は、クラッド層）とコンタクト層の形成において、In組成の異なる２種類の半導体層（一方が、Inを含まなくてもよい）からなる超格子構造領域を設け、この領域のIn組成を大きくした半導体層（Inを含まない層に対してはInが導入された層）の原子層オーダの薄膜成長に同期させて、これにｐ型不純物を変調ドープする手法を用いる。ｐ型不純物には、例えばMg又はZnを単体又は有機金属化合物の原料として用い、分子線エピタキシー(ＭＢＥ)法又は有機金属気相成長(ＭＯＶＰＥ)法により導入する。光導波層をＧａＮ層又はＡｌＧａＮ層とこれにInを導入した化合物半導体層で構成する場合、ｐ型不純物ドープは、ｐ型光導波層全域における平均的なｐ型キャリア濃度が5×10^{17}～$5\times10^{18}/cm^3$の範囲に入るように行うとよい。また、In組成の異なる２種類のGaInN層からなるｐ型コンタクト層におけるｐ型不純物ドープは、当該コンタクト層全域における平均的なｐ型キャリア濃度が5×10^{18}～$2\times10^{19}/cm^3$の範囲に入るように行うと良い。望ましくは、ｐ側電極方の光導波層及びコンタクト層を全てこの手法による超格子構造で形成する。本発明では、光導波層の実質的な禁制帯幅を大きく変えずに、高濃度の正孔キャリアが得られ、In組成の導入に伴う屈折率の増大を発光活性層における光閉じ込めに活用できる。これらにより、低閾値電流で動作し、素子抵抗や動作電圧を低減した素子を実現する。

【０００７】さらに、本発明のレーザ素子に好ましい付加的な構成要件を規定するなら、第１にIn組成の導入によりｐ型光導波層には圧縮歪又は二軸性格子歪が加わるように構成し、ｐ型光導波層全域において当該In導入層の夫々の膜厚を臨界膜厚未満に抑えると良い。第２に、レーザ素子を構成するための基体となる単結晶の半導体基板は、六方晶系のWurtzite構造を有した(0001)C面を有するサファイア(α-Al_2O_3)基板又は(0001)C面を有する炭化珪素(α-SiC)であると、特に窒化物系化合物半導体からなるレーザ素子の形成に好ましい。この場合、六方晶系Wurtzite構造基板上に光導波路構造を設ける際に、導波路を形成する方向を基板の(11-20)A面に平行であるか、或いは垂直となる方向に設定するとよい。また、光導波路は矩形状の断面形状を有したストライプ構造として、発光活性層の横方向に対して実屈折率差を設けて基本横モードが安定に導波される埋め込み型(ＢＨ)ストライプ構造に構成してもよい。矩形状の光導波路構造を構成する結晶層は絶縁膜マスクと選択成長技術により、ＢＨストライプ構造を形成するとよい。第３として、半導体レーザの活性領域における発光活性層は単一の量子井戸層で構成しても複数の量子井戸からなる多重量子井戸構造としてもよく、発光活性層とこれに電子又は正孔（キャリア）を閉じ込める障壁層の材料選定の自由度を拡げるべく、発光活性層を格子歪を導入した歪量子井戸層により構成した単一或は多重歪量子井戸構造としてもよい。

【０００８】上述の素子構成に特徴的な作用の根拠について、次に説明する。

【０００９】ｐ型光導波層の正孔キャリア濃度を従来よりも高レベルに活性化させ設定するために、上記のIn組成の変調構造に同期させてｐ型不純物を導入する手法を適用する。In元素はどの半導体材料に対しても、その半導体の禁制帯幅を小さくする方向に作用する。特に、窒化物半導体材料に対しても、禁制帯幅を小さくし、価電子帯と不純物準位の間隔を相対的に狭くするので、ｐ型不純物のキャリア活性化を促進することになる。例えば、GaN結晶層に対してGaInN結晶層とすることにより、同じｐ型不純物量でも活性化率を向上できるので、高い正孔キャリア濃度が設定できる。従って本発明によれば、半導体レーザ素子の光導波層において$10^{19}/cm^3$までの正孔キャリア濃度を任意に設定できる。

【００１０】背理法を用い手本発明の説明を更に続け

る。例えば光導波層にIn組成を導入していくと、この禁制帯幅が小さくなり、発光活性層の禁制帯幅に近づくと、導波光が吸収を受けることになる。この問題に対し、本発明では、In組成を原子層オーダで変調させた超格子ヘテロ構造として、活性層から発光した導波すべき光の光導波層による吸収を防ぐ。つまり、ｐ型光導波層では、原子層オーダでIn組成を変調するのと同期させてｐ型不純物を導入し、禁制帯幅を大きく減少させないために超格子ヘテロ構造としている。因みに原子層オーダの半導体層とは、例えばこれを構成する１原子の大きさ（直径）５．１６６Åを基準として、数原子層厚分、具体的には１０Å前後（原子は千鳥格子状に積層されるため）の厚さを有するものと規定される。また、ｐ側電極と接触するｐ型コンタクト層はIn組成比の異なる２種のｐ型GaInN層からなる超格子構造とするが、In組成をさらに大きく変調させて（高In濃度層と低In濃度層のIn組成比の差を大きくして）この超格子構造に圧縮歪を導入して価電子帯のバンド構造を曲げることにより、正孔キャリア濃度をより活性化させて高い導電率を達成する。本発明によるｐ側電極とｐ型コンタクト層の接触抵抗は、$1〜5\times10^{-6}\,\Omega cm^2$にまで小さく改善できた。

【００１１】また、本発明によりｐ型光導波層の正孔キャリア濃度は高くなるため、その擬フェルミレベルをより高く設定して、発光活性層に対するｐ型光導波層のエネルギー障壁を大きく設定できる。このため、活性層からのオーバーフローキャリア（発光に寄与することなく活性層からｐ型光導波層へ入る電子）を抑制できるので、活性層におけるキャリア閉じ込めを改善することが可能であった。素子特性に対しては、低閾値動作や高温下での安定動作という効果も見られた。

【００１２】活性層近傍にIn組成を変調した超格子ヘテロ構造を設けることは、In組成を導入しない光導波層に比べて、活性層における光閉じ込め係数を大きく設計できることにつながる。これは、In組成を導入した結晶層の屈折率を大きくできることによるもので、In組成の大きさや導入した繰り返し薄膜層の膜厚や超格子構造の総膜厚によって、活性層の光閉じ込めを設計して調節することが可能である。この光閉じ込め係数を最適設計することにより、低閾値高効率動作や高温動作を得ることができ、また遠視野像のアスペクト比を調整することができる。

【００１３】以上により、素子の低抵抗化とレーザ発振時の動作電圧を低減することが可能であった。また、基本横モードの安定化を図ることができる屈折率導波ストライプ構造を適用することにより、素子の低閾値や高効率動作を達成した。

【００１４】

【発明の実施の形態】以下、実施例１乃至５及びこれらの関連図面に記した本発明の実施の形態により、本発明を詳細に説明する。

【００１５】<実施例１>本発明の一実施例を図１（ａ）と（ｂ）により説明する。まず図１（ａ）の(0001)C面を有するサファイア(α-Al_2O_3)基板１上に、有機金属気相成長法によりアンモニアNH_3を供給しながら温度1000℃から1200℃の範囲で基板を熱処理した後、温度450〜550℃においてGaNバッファ層２を成長し，温度1000〜1100℃においてｎ型GaN光導波層３，ｎ型AlGaN光導波層４，アンドープGaN量子障壁層及びアンドープGaInN量子井戸層からなる圧縮歪多重量子井戸活性層５，ｐ型AlGaN/AlGaInN超格子ヘテロ構造光導波層６，ｐ型GaN/GaInN超格子ヘテロ構造光導波層７，ｐ型GaInN/GaInN超格子ヘテロ構造コンタクト層８を設ける。この際、ｐ型光導波層６とｐ型光導波層７及びｐ型コンタクト層８は、すべてIn組成を変調させた超格子ヘテロ構造とし、図１（ｂ）に模式的に示すように原子層オーダの超格子薄膜層の繰り返しにより光導波層及びコンタクト層を形成し、ｐ型不純物のMgをIn組成の変調構造に同期させて導入している。従って、光導波層６のAlGaInN層、光導波層７のGaInN層、コンタクト層８のGaInN層（In組成大の方）にはMgがドープされ、光導波層６のAlGaN層、光導波層７のGaN層、コンタクト層８のGaInN層（In組成小の方）には何もドープされていない。ｐ型不純物Mgは有機金属化合物の形で、ｐ型光導波層６とｐ型光導波層７に$5\times10^{17}〜2\times10^{18}/cm^3$の範囲で、ｐ型コンタクト層８に$5\times10^{18}〜2\times10^{19}/cm^3$の範囲で夫々導入した。次に、フォトリソグラフィーとエッチング加工により、図１（ａ）に示すように、結晶層の一部を層３に到るまで除去する。その後、絶縁膜９を設けて、窓領域ストライプ方向を該α-Al_2O_3基板１における(11-20)A面と平行な方向に形成する。また、リソグラフィーにより、ｐ側電極１０とｎ側電極１１のパターンを蒸着する。最後に、光導波路ストライプに対して垂直な方向に基板を劈開することによって、図１（ａ）に示す素子断面を得る。

【００１６】本実施例によると、ｐ型GaN及びAlGaN光導波層の正孔キャリア濃度を従来よりも一桁近く高く活性化できたので、ｐ型光導波層の抵抗率を低減できた。さらに、ｐ型コンタクト層とｐ側電極の接触抵抗も$1〜5\times10^{-6}\,\Omega cm^2$にまで小さく改善することが可能であった。これにより、本実施例の素子抵抗は従来の素子の1/5から1/10（各層のIn組成比に依存）に低減でき、さらに注入電流２０ｍＡ時の素子動作電圧は従来の３．６Ｖに対して３．１〜３．３Ｖにまで低減できた。また、本発明により正孔キャリア濃度を高くできるため、ｐ型光導波層の擬フェルミレベルをより高くできる。これにより、発光活性層に対するｐ型光導波層のエネルギー障壁を大きくできた。このことは、活性層からのオーバーフローキャリアを抑制し、活性層におけるキャリアの閉じ込めを改善させることが可能であった。さらに、ｐ型光導波層にはInが含まれているので、その屈折率は高くなり、発光活性層近傍の光閉じ込め係数を大きくしている。本素

子構造は、利得導波型のストライプ構造を有しており、室温においてレーザ動作が可能であり、青紫色波長域の４１０～４３０ｎｍの範囲でレーザ発振する素子を得た。

【００１７】＜実施例２＞本発明の他の実施例を図２により説明する。実施例１と同様にして素子を作製するが、ｐ型のGaN／GaInN超格子ヘテロ接合型光導波層７まで形成した後、フォトリソグラフィーにより光導波層７の上面中央部にストライプ状に延伸する絶縁膜マスクを形成し、更にこの絶縁膜マスクを用いたエッチングにより、ｐ型AlGaN／AlGaInN超格子ヘテロ接合型光導波層６の上面が露出するまで光導波層７を除去してリッジストライプを形成する。次に、絶縁膜マスクを利用して、ｎ型GaN電流狭窄層１２を選択成長する。絶縁膜マスクを除去した後、ｐ型GaN/GaInN超格子ヘテロ構造埋め込み層１３とｐ型GaInN/GaInN超格子ヘテロ構造コンタクト層８を設ける。次に、フォトリソグラフィーとエッチング加工により、図２に示すように、リッジストライプ構造の両側を層３に到るまで除去する。その後、実施例１と全く同様にして、素子を作製する。

【００１８】本実施例によると、電流狭窄層１２を設けた屈折率導波構造にできているので、実施例１よりも低閾値の素子を得た。閾値電流は、実施例１に比べて、1/3から1/5にまで低減できた。発振波長は、青紫色波長域の４１０～４３０ｎｍの範囲であった。

【００１９】＜実施例３＞本発明の他の実施例を図３により説明する。まず、実施例１や２と同様にして、ｎ型のGaN光導波層３まで設ける。次に、フォトリソグラフィーとエッチングにより、光導波層３上面にストライプ状に延伸した２条の選択成長用の絶縁膜マスク１４を形成する。その後、ｎ型GaN光導波層３の再成長を皮切りに、ｎ型AlGaN光導波層４，アンドープGaN量子障壁層及びアンドープGaInN量子井戸層からなる圧縮歪多重量子井戸活性層５，ｐ型AlGaN/AlGaInN超格子ヘテロ構造光導波層６，ｐ型GaN/GaInN超格子ヘテロ構造光導波層７，ｐ型GaInN/GaInN超格子ヘテロ構造コンタクト層８を有機金属気相成長法により選択成長させる。即ち、光導波層３の再成長からの工程では、結晶成長が２条のストライプ状絶縁膜マスクで仕切られた領域で選択的に生じているため、図３に示すような矩形断面を有する結晶の積層体が形成される。その後、絶縁膜９を形成して、リソグラフィーにより、ｐ側電極１０とｎ側電極１１のパターンを蒸着形成する。さらに、導波路とは垂直な方向に基板を劈開することによって図３に示す素子断面を得る。

【００２０】本実施例によると、実屈折率差によって基本横モードを安定に導波するＢＨストライプ構造を作製できた。本素子では、実施例１の素子よりも、活性層横方向の屈折率差が大きくとれるので、導波光を安定に伝搬できる。さらに、電流狭窄効果も大きいので、低閾値動作が可能であった。閾値電流は、実施例２に比べて、さらに1/2から1/3にまで低減できた。発振波長は、青紫色波長域の４１０～４３０ｎｍの範囲であった。

【００２１】＜実施例４＞本発明の他の実施例を図４により説明する。実施例３と同様にして素子を作製するが、実施例３に相当するＢＨストライプ構造の外側に図４に示すようなダミーパターンを含む絶縁膜マスク１４を利用して実施例３と同じ結晶層を選択成長する。ダミーパターンとは、図３の素子形成で設けた２条のストライプ状の絶縁マスクの外側に、これらに略平行に１条ずつストライプ状の絶縁マスクを設けて形成される、換言すれば新たに形成された選択成長領域（絶縁膜マスクで仕切られた領域）である。ダミーパターン上のストライプに対しては絶縁膜マスク９を図４のようにしてカバーして、電流を注入しないようにする。その後、電極を蒸着しかつ基板を劈開することにより、図４に示す素子断面を得る。

【００２２】本実施例によると、ダミーパターンにより中央部のＢＨストライプ構造における導波路結晶層の結晶性を改善できた。この結果、実施例３に比べて低閾値動作が可能であり、閾値電流を実施例３よりさらに2/3から1/2に低減できた。量子効率についても、実施例３より３０％から５０％増大できた。発振波長は、青紫色波長域の４１０～４３０ｎｍの範囲であった。

【００２３】＜実施例５＞本発明の他の実施例を説明する。本実施例では、既に説明した図１乃至４のいずれかの素子構成を有する半導体レーザ素子において、基板１に六方晶系のWurtzite構造であり基板面方位が(0001)C面であるｎ型の炭化珪素(α-SiC)を用い、その上にｎ型GaNバッファ層を設けて、実施例１乃至４のいずれかの記載に準じて素子を作製する。

【００２４】本実施例によると、基板がｎ型の導電性を有するために、ｎ側の電極は基板裏面に蒸着して、基板上下面に電流を通すことができた。これにより、チップ素子の組立時において、接合部を下にしたマウントが可能となるので、熱放散性を向上できた。本実施例では、上記実施例よりも、高い温度で動作するレーザ素子を得た。

【００２５】

【発明の効果】本発明では、特にIII-V族窒化物半導体材料において、ｐ型光導波層の正孔キャリア濃度を10^{19}/cm^3まで任意に設定できるようになり、従来よりも一桁近く高くキャリアを活性化できるので、ｐ型光導波層の抵抗率を低減できた。さらに、ｐ型コンタクト層とｐ側電極の接触抵抗を低減し、1～5×10^{-6} Ωcm^2にまで小さく改善できた。本発明の素子ではその抵抗を従来より1/5から1/10に低減するとともに、注入電流２０ｍＡ時の素子動作電圧を従来は３．６Ｖであったのに対して３．１～３．３Ｖにまで低減できた。また、高い正孔キャリア濃度により、ｐ型光導波層における擬フェルミレベルを

より高くできるので、活性層に対するｐ型光導波層のエネルギー障壁を従来技術より大きく設定できた。これは、活性層におけるキャリアの閉じ込めに有効であった。さらに、ｐ型光導波層には、屈折率を高くするIn組成が取り込まれているので、発光活性層近傍の光閉じ込め係数を大きく設計できた。これらの効果によって、本発明の素子では、低素子抵抗でかつ低動作電圧で動作し、低閾値動作を図ることができた。本発明により、AlGaInN材料からなるレーザ動作を室温において確認し、発振波長４１０～４３０ｎｍの範囲で青紫色の波長領域でレーザ発振する素子を得た。

【００２６】本発明では、(0001)C面を有したWurtzite構造のサファイアや炭化珪素単結晶基板上に作製したAlGaInN半導体レーザ素子について説明したが、他の半導体材料系であるAlInGaAs/GaAs、AlGaInP/GaAs、GaInAsP/GaInAs/InP、AlInAs/GaInAs/InP等を用いた半導体レーザ素子に適用できることはいうまでもない。

【図面の簡単な説明】

【図１】本発明の実施例１を説明するための図であり、（ａ）は素子構造縦断面図、（ｂ）は超格子構造ｐ型不純物変調ドープ結晶層である。

【図２】本発明の実施例２を示す素子構造縦断面図である。

【図３】本発明の実施例３を示す素子構造縦断面図である。

【図４】本発明の実施例４を示す素子構造縦断面図である。

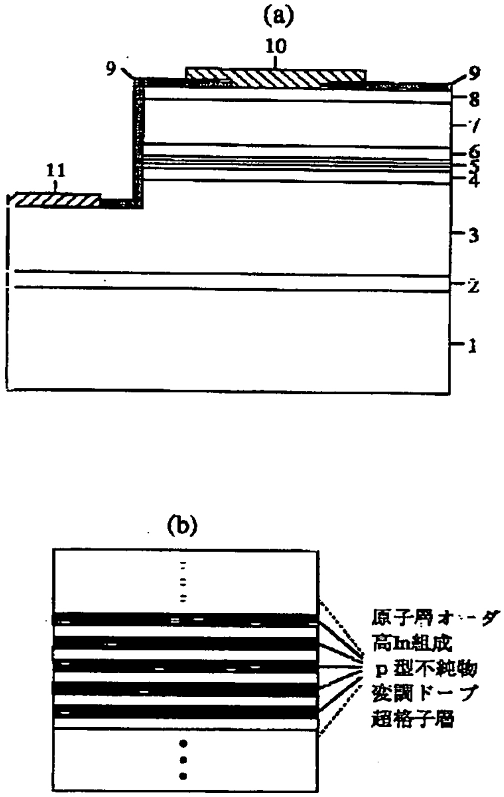
【符号の説明】

１…(0001)C面サファイア単結晶基板、２…GaNバッファ層、３…ｎ型GaN光導波層、４…ｎ型AlGaN光分離閉じ込め層、５…GaInN/GaN圧縮歪多重量子井戸構造活性層、６…ｐ型AlGaN光分離閉じ込め層、７…超格子ヘテロ構造ｐ型不純物変調ドープGaN光導波層、８…超格子ヘテロ構造ｐ型不純物変調ドープGaInNコンタクト層、９…絶縁膜、１０…ｐ側電極、１１…ｎ側電極、１２…ｎ型GaN電流狭窄層、１３…超格子ヘテロ構造ｐ型不純物変調ドープGaN埋め込み層、１４…選択成長用絶縁膜マスク。

【図１】

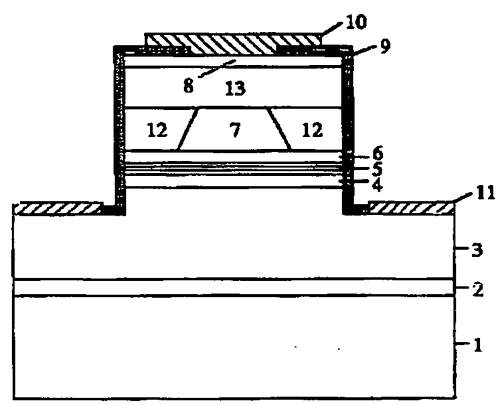
図１

(a)



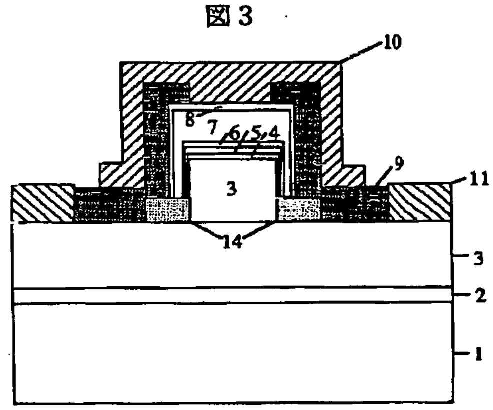
【図２】

図２



【図３】

図３



【図４】

図４